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ADVANCED.

LIST OF TOPICS.

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I. LOGARITHMS.

A. THEORY.

1. The logarithm of 1 to any base is zero.

2. The logarithm of the base is 1.

3. The logarithm of the product of two numbers equals the sum of the logarithms of those numbers.

4. The logarithm of the quotient of two numbers equals the difference of the logarithms of those numbers.

5. (*a*) The logarithm of any power of a number equals the logarithm of the number multiplied by the exponent of the power. (*b*) The logarithm of any root of a number equals the logarithm of the number divided by the index of the root.

6. (*a*) Rule for finding the characteristic of any number using the base 10. (*b*) Use of tables; finding the logarithm of any number, and finding the number from the given logarithms, including interpolation.

B. APPLICATIONS.

1. Questions to be solved without tables; as, $\log_2 4 = ?$ $\log_8 \frac{1}{2} = ?$ If $\log_{10} 2 = .30103$, and $\log_{10} 3 = .47712$, find $\log_{10} 24$, $\log_{10} \frac{2}{3}$, $\log_{10} 32$, $\log_8 2$. What number, using the base 3, has a logarithm -3? If $\log_{10} 3 = .47712$, find how many places in 3^{200}. Write in form for logarithmic use $\log \frac{\sqrt{ac^2(b-c)}}{bc}$.

2. Use of logarithmic tables in performing arithmetic computations; as, 98.712^5, $\sqrt[7]{102.847}$, $\frac{\sqrt{432.9203} \times \sqrt{41.52}}{.024371}$, $\frac{2^{-\frac{1}{5}} \times (-7)}{300}$.

3. Solution of simple cases of exponential equations; as, $3^x = 7$, $3^{2x+3} = 2^{5x-7}$, $5^{x-y} = 3$ and $2^{3x+y} = 5$.

Note.—Management of a negative factor in logarithmic computation. Distinction between the logarithm of a negative number and a negative logarithm.

II. PERMUTATIONS AND COMBINATIONS.

A. Theory.

1. (*a*) The number of ways in which two things can both be done is the product of the number of ways in which the first can be done by the number of ways in which the second can be done. (*b*) The number of ways in which one or the other of two things can be done is the sum of the number of ways in which each alone can be done.

2. ${}_nP_r = n(n-1)(n-2)\cdots(n-r+1)$, including ${}_nP_n = n$.

3. ${}_nC_r = \dfrac{n(n-1)(n-2)\cdots(n-r+1)}{1\ 2\ 3\cdots r} = \dfrac{\underline{|n}}{\underline{|r}\ \underline{|n-r}} = {}_nC_{n-r}$.

4. ${}_nP_n$ (where k are of one kind and l of another) $= \dfrac{\underline{|n}}{\underline{|k}\ \underline{|l}}$.

5. Simple combination formulas; as, ${}_nC_r + {}_nC_{r+1} = {}_{n+1}C_{r+1}$,

$${}_nC_1 + {}_nC_2 + {}_nC_3 + \text{etc.} \cdots + {}_nC_n = 2^n - 1.$$

B. Applications; as,

Using the letters of the word "certain," how many arrangements of all the letters? of any five of the letters? of five of the letters of which two are vowels and the others consonants? of all the letters in a circle? of all the letters if *c* and *n* are the first and last? of all the letters if two vowels are first and last? of these letters and two other letters *a*? of all the letters if *r* and *t* can not be separated? of all the letters if *r* and *t* can not be together? How many sets of four letters can be chosen? of two vowels? of a vowel and three consonants? of five letters containing *a*? of five letters not containing *a*? If there are three ways to go from *A* to *B*, and two to go from *B* to *C*, how many to go from *A* to *C*? In how many ways can six people be seated in ten numbered seats? If ten teams in a league wish to play so that each team meets each other team twice, how many games are played? How many different throws can be made with two dice? etc.

Note 1.—Easy exercises in choice and chance (or probability) should be given.

Note 2.—Use the symbol ! or ⌊ for factorial in formulas.

III. COMPLEX NUMBERS.

Note.—This is a somewhat more extended treatment than that given in X of Elementary and Intermediate.

A. Theory. (Using the general form $a+bi$.)

1. The sum or difference of complex numbers in the general form can be reduced to a complex number in the general form.

2. The product of complex numbers can be reduced to a complex number in the general form.

3. The quotient of two complex numbers can be reduced to a complex number in the general form.

4. The modulus; its definition and length; use in graphical representation (see X of Elementary).

B. Applications.

To simplifying imaginary expressions, including such questions as, Extract the square root of $2-3i$; find and plot the three cube roots of 1; how long is the modulus of each? Simplify and represent graphically $\frac{3+2i}{5-3i}$ and of $\frac{i+7}{i-7}$, their sum and their difference, and test the results by adding and subtracting the complex numbers.

IV. DETERMINANTS.

A. Theory.

1. If the rows of a determinant are changed to columns, and the columns to rows, the determinant is not changed in value.

2. (*a*) The interchange of two rows or of two columns changes the sign of the determinant. (*b*) If two rows or two columns are identical, the determinant equals zero. (*c*) If the substitution of one quantity for another in the constituents of a determinant (as, a for b) makes two rows or two columns identical, then the difference of those quantities (as, $a-b$) is a factor of the determinant.

3. (*a*) A factor of any row or of any column is a factor of the determinant. (*b*) If each constituent in a row or in a

column is the sum of n terms, the determinant can be expressed as the sum of n determinants. (c) Equimultiples of the constituents of any row (or of any column) can be added to, or taken from, the corresponding constituents of any other row (or column) without changing the value of the determinant.

4. (a) If the constituents of a row (or of a column) be multiplied, each by its co-factor, the sum of the products so obtained will equal the original determinant. (b) If the constituents of a row (or of a column) be multiplied, each by the co-factor of the corresponding constituent of a different row (or column), the sum of the products so obtained equals zero.

B. APPLICATIONS.

1. Evaluation of a determinant: (a) of the third degree; (b) of any degree, by the use of minors; (c) of any degree, by adding or subtracting the constituents of one row (or column) from another so as to obtain zero constituents, and so to reduce the degree of the determinant.

2. The solution of simultaneous linear equations.

3. Finding the condition that n linear homogeneous equations in n variables have a common solution other than the zero solution.

4. Factoring determinants by the method $A1(c)$.

NOTE.—Introduce the subject by the solution of a set of linear equations in two variables. Numerical examples.

V. THEORY OF EQUATIONS.

NOTE.—Review factor theorem, remainder theorem, synthetic division. See II, C, notes 1 and 2.

A. GENERAL THEORY.

1. An equation of the nth degree has n roots. (Assume that any equation has at least one root.)

2. (a) Relation between coefficients and roots; simple cases of symmetric functions of the roots; as, find the sum of the reciprocals of the roots of a given equation. (b) Application to (1) depression of an equation; as, if one root of a given equation of third degree is r, write the quadratic equation having its other two roots; (2) formation of an equation having given roots; as, $a \pm bi, c$; $2, 3, -4, 5$.

3. (*a*) If the coefficient of the highest power of the variable in an equation is one, and the other coefficients are integral, the equation can not have a rational irreducible fraction as a root. (*b*) If an equation has rational coefficients, quadratic surd roots occur in conjugate pairs: if an equation has real coefficients, imaginary or complex roots occur in conjugate pairs.

4. Transformation of an equation by: (*a*) Multiplying the roots by a constant; including changing the signs of the roots by using -1; as, multiply the roots of $2x^3+3x^2-4x+7=0$ by 3; change the signs of its roots; change it into an equation having the coefficient of x^3, 1, and the other coefficients integral; divide each root by 3. (*b*) Increasing or diminishing each root by a given constant; also, by means of this, making the coefficient of the second highest power of the variable equal to zero; as, in the equation in (*a*), add 2 to each root; take three from each root; make the coefficient of x^2 zero.

B. GRAPHICAL REPRESENTATION OF FUNCTIONS.

1. Graphs of functions of one variable.

2. Interpretation of the graphs, including: (*a*) finding integral roots of the function, (*b*) locating and approximating rational fractional and surd roots, (*c*) finding those values of the variable that give positive or negative values of the function, (*d*) approximating those values of the variable that give maximum or minimum values of the function.

C. CHARACTER AND LOCATION OF THE ROOTS.

1. Descartes' rule of signs (without proof). Its use in finding the possible number of positive and negative roots, as in $x^3+x^2-3x+5=0$, and in finding the exact number of positive, negative and imaginary roots; as, find the character of the roots of $x^3+x-3=0$.

2. Location of the roots by the signs of the remainders obtained by substitution or division. Special importance should be given to the substitution of $-\infty$, 0, and $+\infty$.

3. By graphs; see B, 2 (*b*).

D. SOLUTION OF EQUATIONS.

1. Commensurable roots, by substitution or division.

2. Incommensurable roots, by Horner's method of approximation.

NOTE.—The finding of incommensurable roots should not be made unnecessarily burdensome by carrying the work to a useless number of decimal places. Two decimal places is probably enough for most examples of this kind.

NOTE.—While the topic of mathematical induction is not included in this syllabus, it may be desirable to give some idea of that method of reasoning and to apply it to the binomial theorem and perhaps to other simple investigations.

The committee is fully persuaded that no other topics of algebra should be required of secondary school pupils at this time, and it wishes to call the attention of both colleges and preparatory schools to the unfortunate and harmful lack of reasonable uniformity in the requirements of the colleges in advanced algebra. If the committee is justified in the belief that the topics included in this syllabus provide a sufficient preparation for the needs of college work, then the colleges should adjust their entrance requirements in algebra as near as may be to this syllabus.

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